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FIELD OF THE INVENTION

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Short-range WLAN protocols such as IrDA and Bluetooth technology allow for the replacement of the many proprietary cables that connect one device to another with one universal short-range radio link. Short range WLAN protocol technology could replace the cumbersome cables used today to connect a laptop to a cellular telephone or between other devices such as printers, personal digital assistants, desktops, fax machines, keyboards, joysticks or virtually any other digital device. Refrigerators, microwave ovens, dish washers, laundry washers & dryers, stereo, television, digital video disks, video games, lighting, irrigation, cooling and heating systems among others may also take advantage of such short-range radio links.

Potential applications of these low-power, short-range, protocols are wireless connection of peripherals devices, high-speed data transfers to desktop computers and wireline networks, and establishment of short-range "ad hoc networks" between similar wireless communication devices. Two or more units sharing the same channel is called an ad hoc network. In an ad hoc network one of the units functions as the master while the others function as slaves. For example, in a Bluetooth system, up to seven active slaves can exist in an ad hoc network but many more can remain locked to the same master in a so-called parked state. These parked units cannot be active on the channel, but remain synchronized to the master. The master always controls the channel access for both the active and the parked units. The master in a Bluetooth system controls the traffic across the channel using a polling scheme. Once an ad hoc network has been established, master-slave roles can be exchanged. To avoid collisions, communication between two slaves can only be accomplished through the master unit.

Many short-range communication WLANs such as the Bluetooth system further supports scatternets. A scatternet is the combination of two or more ad hoc networks with overlapping coverage area. Each ad hoc network can only have one master. However, a master in one ad hoc network can participate as a slave in another and slaves can also participate in different ad hoc networks on a time division multiplex basis. Ad hoc networks within a scatternet are not time or frequency synchronized. Each ad hoc network uses its own hopping sequence.

The devices participating in an ad hoc network each include different processes capabilities. For example, some have more processing power, some have access to an unlimited power source, and some include a variety of powerful applications. Further, usage profiles vary for each device. For example, printers may have a low usage profile and thus have some additional free computing time. Similarly, the personal computer in an office may have a high usage profile but may be the only device that has a particular application on board. One personal computer may have access to a higher speed modem.

What is needed is a system and method for dynamically assigning processes within a WLAN such as an ad hoc network to optimize the shared capabilities of each individual unit within the network.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references denote similar elements, and in which:

FIG. 1 is a block diagram of a communication system having devices that operate on both a short range and a secondary protocol;

FIG. 2 is a block diagram of a block diagram of an ad hoc network for use within the communication system of FIG. 1;

FIG. 3 is a block diagram of a smart network access point for use in the ad hoc network of FIG. 2 in accordance with the present invention;

FIG. 4 illustrates the communication between devices within the ad hoc network of FIG. 2 in accordance with the present invention; and

FIG. 5 is a flow chart illustrating the operation of the ad hoc network of FIG. 2 in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which may be embodied

in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. Further, the terms and phrases used herein are not intended to be
5 limiting; but rather, to provide an understandable description of the invention.

Referring to FIG. 1, a communication system **10** having devices that operate on a short-range protocol system **14** and preferably on a secondary protocol system **12** is illustrated. The secondary protocol system **12** as shown
10 in FIG. 1 includes a base station **16** with a co-located base transmitter **18** and base receiver **20** covering a wide area range **22** as shown. A typical secondary protocol could be Motorola's ReFLEX™ messaging protocol.

It will be appreciated by one of ordinary skill in the art that the secondary protocol system **12**, in accordance with the present invention, can function
15 utilizing any wireless RF channel, for example, a one or two-way pager channel, a mobile cellular telephone channel, or a mobile radio channel. Similarly, it will be appreciated by one of ordinary skill in the art that the secondary protocol system **12** can function utilizing other types of communication channels such as infrared channels, audio channels, and local
20 area networks. In the following description, the term "secondary protocol system" refers to any of the systems mentioned above or an equivalent.

In one embodiment, each of the devices (i.e.: a personal computer **24**, a wireless communication device **26**, a personal digital assistant **28**, a printer **30**, and a computer **32**) is a device using a short-range WLAN protocol, such
25 as Bluetooth technology. It will be appreciated by one of ordinary skill in the art that the short-range WLAN protocol, in accordance with the present invention, can function utilizing any short-range wireless protocol such as IrDA, HomeRF, and IEEE 802.11. Using the short-range WLAN protocol, each device will establish a list of "partners",

30 Using the short-range WLAN protocol, a first device, such as the personal computer **24** (User A), and one or more of the potential partner

devices (the wireless communication device **26**, the personal digital assistant **28**, the printer **30**, or the computer **32**) agree to form an ad-hoc network.

This network is defined by a list of active partners stored in Unit A. The list may contain available resources for each device, including battery life,
5 access to wide area networks, application availability, utilization, etc.

FIG. **2** is a block diagram of an ad-hoc network **36** for use within the communication system **10** of FIG. **1** in accordance with the present invention.

The ad hoc network **36**, for example, can be a subset of the short-range protocol system **14** of FIG. **1**. The ad hoc network **36** includes a plurality of

10 devices **40** such as the wireless communication device **26**, the personal digital assistant **28**, the printer **30**, and the computer **32**. In one embodiment, as illustrated in FIG. **2**, the ad hoc network **36** further includes a smart network access point **38**. Within the ad hoc network **36** of FIG. **2**, an initial coordinator functions as the master and the plurality of devices **40** function as the slaves.

15 The initial coordinator, for example, can be the smart network access point **38** or alternatively, the initial coordinator can be one of the plurality of devices **40**.

It will be appreciated by one of ordinary skill in the art that each of the plurality of devices **40** in accordance with the present invention, can be a mobile cellular telephone, a mobile radio data terminal, a mobile cellular
20 telephone having an attached data terminal, or a two way pager, such as the "Pagewriter 2000X" manufactured by Motorola Inc. of Schaumburg, Illinois. Similarly, each of the plurality of devices **40**, in accordance with the present invention, can be a printer, a personal computer, or a personal digital assistant. In the following description, the term "device" refers to any of the
25 devices mentioned above or an equivalent.

It will be further appreciated by one of ordinary skill in the art that the ad hoc network **36** can include only the plurality of devices **40** in one embodiment without the use of the smart network access point **38**. In this alternative embodiment, one or more of the plurality of devices can take the role of initial
30 coordinator or resource manager.

As illustrated in FIG. **3** in an embodiment where the smart network access point **38** functions as the initial coordinator, the smart network access

point **38** preferably functions as a transformer from the short-range WLAN protocol to the secondary network **12** such as a local area network (LAN) or a wireless communication system (see FIG. 1). It will be appreciated by one of ordinary skill in the art that one of the plurality of devices **40** alternatively can function as the initial coordinator and that the functionality described herein for the smart network access point **38** can equally apply to one of the plurality of devices **40**. The smart network access point **38** includes an ad hoc network interface **42**, a secondary system interface **44**, a processor **46** and a resource management application **48**.

Coupled to the ad hoc network interface **42** and the secondary system interface **44** is the processor **46** utilizing conventional signal-processing techniques for processing received information. Preferably, the processor **46** is similar to the MC68328 micro controller manufactured by Motorola, Inc. of Schaumburg, Illinois. It will be appreciated by one of ordinary skill in the art that other similar processors can be utilized for the processor **46**, and that additional processors of the same or alternative type can be utilized as required to handle the processing requirements of the processor **46**.

In a preferred embodiment, the initial coordinator, such as the smart network access point **38**, includes the resource management application **48** coupled to the processor **46**. The smart network access point **38** performs resource management functions within the resource management application **48** using a processor command **50** sent from the processor **46**. The resource management application **48** sends an application response **52** in reply to the processor command **50**. The resource management application **48** preferably includes a resource-tracking list **54**. The resource management application **48** can be hard coded or programmed into the smart network access point **38** during manufacturing, can be programmed over-the-air upon customer subscription, or can be a downloadable application. It will be appreciated by one of ordinary skill in the art that other programming methods can be utilized for programming the resource management application **48** into the smart network access point **38**.

The resource management application **48** preferably is programmed to enable utilization of a required resource from the resource-tracking list **54**. The resource-tracking list **54** includes a plurality of resource information **56** for each of the plurality of devices **40** of the ad hoc network **36**. For example, the plurality of resource information **56** can include device battery life, device battery capacity, device processing power, and access to the secondary network for each of the plurality of devices **40**. The resource management application **48**, in response to the processor command **50**, preferably accesses the resource-tracking list **54**. The resource management application **48** is programmed to identify an available resource from the resource-tracking list **54** using the plurality of resource information **56** stored in the resource-tracking list **54** by using predetermined algorithms, as is well known in the art. The resource management application **48** is preferably programmed with a set of rules identifying the resource to allocate in response to the processor command **50**. When the resource management application **48** identifies the available resource, the resource management application **48** sends the application response **52** to the processor **46**. The processor **46**, in response to receipt of the application response **52**, enables the use of the available resource by the requesting device.

Referring back to FIG. **2**, the present invention provides a novel way of dynamically assigning a particular task to one of the plurality of devices **40** within the ad hoc network **36**. For example, as illustrated in FIG. **2**, the smart network access point **38** can be located in a public place and the plurality of devices **40** can initially be three devices, for example, the personal digital assistant **28**, the printer **30**, and the computer **32**. The smart network access point **38** and each of the plurality of devices **40** preferably operate using one of many secondary, short-range WLAN protocols as described herein. It will be appreciated by one of ordinary skill in the art that the secondary, short-range WLAN protocol, in accordance with the present invention, can function utilizing any short-range wireless protocol such as Bluetooth, IrDA, HomeRF, and IEEE 802.11. When a fourth device, such as the wireless communication device **26**, comes within the range of the smart network access point **38**, it can

decide to become part of the ad hoc network **36**. For example, it can request to be a member of the ad hoc network **36** for the purpose of downloading a long electronic mail document **58** (E-mail) originally written in a language other than English. The smart network access point **38** processes the request from the wireless communication device **26** and identity from the resource-tracking list **54** (see FIG. **3**) of the smart network access point **38**, the available resource to translate the E-mail document **58**. Further it instructs the resource identified to translate the email where to return the translated email

For example, when the smart network access point **38** has greater resources available (memory, processing power, energy source) than the other plurality of devices **40**, the smart network access point **38** can run the translation application to translate the E-mail document **58**, while still serving the other three devices.

Alternatively, when the capacity of the smart network access point **38** is low but still has enough processing power to download the document into another device such as the wireless communication device **26** but not run the application, the smart network access point **38** can assign the wireless communication device **26** to run the translation application itself to translate the E-mail document **58**.

Alternatively, when both the capacity of the smart network access point **38** and the battery life of the wireless communication device **26** are low, the smart network access point **38** downloads the E-mail document **58** to another device within the ad hoc network **36** that is capable of running the application such as the computer **32**. Once the computer **32** completes the task, it sends the translated document back to the smart network access point **38**, which forwards this information to the wireless communication device **26**.

Alternatively, the computer **32** sends the translated document directly to the wireless communication device **26**.

FIG. **4** illustrates one embodiment of the communication between the smart network access point **38**, a requesting device **60**, and a resource device **62** of the ad hoc network **36**. In FIG. **4**, the smart network access point **38**

polls the requesting device **60** by transmitting polling signal **66** in an occupied bandwidth. Preferably, this transmission is of a standard Bluetooth 1.0 type transmission or an equivalent. The requesting device **60**, in response, requests a resource **64** that is dynamically selected by the smart network access point **38**. Initially, it is assumed that a polling signal **66** sent from the smart network access point **38** has just arrived at the requesting device **60** and the smart network access point **38** is maintaining the ad hoc network **36**, e.g., polling the plurality of devices **40** (not shown). When a poll by the smart network access point **38** is not scheduled, the requesting device **60** utilizes its internal resources for performing required tasks.

It will be appreciated by one of ordinary skill in the art that alternatively, the initial coordinator, for example the smart network access point **38** or one of the plurality of devices **40** sets the communication between two devices of the ad hoc network and thereafter the two devices communicate directly with each other without the interference of the initial coordinator.

It will be appreciated by one of ordinary skill in the art that the transmission, in accordance with the present invention, can function utilizing any short-range wireless protocol such as IrDA, HomeRF, and IEEE 802.11. The requesting device **60** then sends a resource request signal **68** to request the usage of a resource from the ad hoc network **36** to the smart network access point **38**. The smart network access point **38** identifies the available resource within the ad hoc network **36** and sends a polling resource signal **70** to the resource device **62** to confirm use of the selected resource of the resource device **62**. The resource device **62** then sends a confirmation signal **72** to the smart network access point **38**. When the smart network access point **38** finds an acceptable resource, the smart network access point **38** sends an acknowledgement signal **74** acknowledging the request of the requesting device **60** including identification of the resource device **62**. When the smart network access point **38** finds the resource identified as unacceptable, the smart network access point **38** will ideally search the resource-tracking list **54** for the best alternative, which is then sent to the requesting device **60**.

FIG. 5 is a flow chart illustrating the one embodiment of the operation of the ad hoc network **36** of FIG. 2 in accordance with the present invention. In Step **76**, a wireless connection is formed between two devices using one a WLAN protocol. Next, in Step **78**, the two devices have stored in memory a common application. Alternatively, one or both devices can have access to the common application via the secondary protocol system **12**. Next, in Step **80**, one of the devices decides to run the common application. Next, in Step **82**, both devices set a decision counter to zero. Next, in Step **84**, the available excess energy of the two devices is compared. For example, one of the devices can have access to an unlimited power source. In this case, the use of this unlimited power source overrides the currently available energy capacity of the other device. In Step **86**, when the battery life of the first device (D1) is lower than the second device (D2), the counter of D1 is incremented by one. In Step **88**, when the battery life of D1 is greater than the battery life of D2, the available capacity of the two devices is compared. In Step **90**, when the capacity of D1 is lower than the capacity of D2, the counter of D1 is incremented by one. In Step **92**, when the capacity of D1 is greater than the capacity of D2, the processing power of the two devices is compared. In Step **94**, when the capacity of D1 is lower than the capacity of D2, the counter of D1 is incremented by one. When the processing power of D1 is greater than the processing power of D2 in Step **92**, and when the counter of D1 has been incremented by one in Steps **86**, **90**, and **94**, next, in Step **96**, the final counter value is calculated. Next, in Step **98**, the counter value of D1 is compared to the counter value of D2. In Step **100**, when the counter value of D1 is lower than the counter value of D2, D1 is used to run the common application. In Step **102**, when the counter value of D1 is higher than the counter value of D2, D2 is used to run the common application. The process then resets to begin again at Step **76**.

To illustrate the method of the present invention, consider a video cellular telephone, which has an application to perform the MPEG4 video compression and decompression. The raw video signal can require a data rate (bandwidth) of several hundred kilobits per second (kbps). When

compressed, the video signal can require as little as 28.8 kbps, depending upon the quality and size of the video image. For macro-cellular connections (i.e.: GSM cellular network) the compressed signal is transmitted over the wireless channel for bandwidth efficiency, in order to support many users.

- 5 The videophone performs both MPEG4 compression and decompression for transmitting and receiving the video signal. The same phone can also be used on a WLAN, which can support higher bandwidths, and typically fewer users. When the video phone connects with the smart network access point 38 using the WLAN protocol, the phone and the smart network access point 10 38 can communicate regarding available bandwidth, MIPs capabilities and devices' processors, and user battery status. As a result, the devices can make a decision for the smart network access point to do the processing intensive MPEG4 video compression and decompression and then transmit the uncompressed video signal to the user's device with a higher bandwidth 15 WLAN protocol. This saves battery power and potentially speeds up the video processing at the expense of consuming WLAN bandwidth and processing resources of the smart network access point. The decision of the smart network access point to perform the video compression and decompression can be made on a frame by frame basis, so the smart network 20 access point 38 can continue to handle other processes intermittently.

Although the invention has been described in terms of preferred embodiments, it will be obvious to those skilled in the art that various alterations and modifications may be made without departing from the invention. Accordingly, it is intended that all such alterations and 25 modifications be considered as within the spirit and scope of the invention as defined by the appended claims.

What is claimed is: